Effect of cracks and initial moisture content on the infiltration rate of Sharkey clay

James Butler Allen

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Effect of Cracks and Initial Moisture Content On the Infiltration Rate Of Sharkey Clay

James B. Allen and Harry J. Braud, Jr.

Louisiana State University and Agricultural and Mechanical College Agricultural Experiment Station Doyle Chambers, Director
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Effect of Cracks and Initial Moisture Content on the Infiltration Rate of Sharkey Clay

James B. Allen and Harry J. Braud, Jr.¹

Introduction

When irrigation of certain soil types is proposed, one of the first questions raised is, "What is the soil's infiltration rate?" In the case of certain impermeable clay "problem" soils, determination of the infiltration rates is quite important. These soils have such low permeability that they often remain flooded long enough for crops to suffer after an irrigation. Yet the low permeability also makes it difficult to apply enough water to last the growing crop more than a few days even though the soil has a high water-holding capacity.

The above characteristics are typical of Sharkey clay. Sharkey clay and related soils occupy vast acreages of bottom lands in the lower Mississippi River flood plain. It is a dark colored, fertile soil very high in clay content and rather impermeable. When it dries out, deep cracks form and divide the soil into a maze of blocks. Although the infiltration rate of the soil is very low, the cracks cause dry soil to absorb water rapidly.

Figure 1 shows a typical cracked area of Sharkey clay. Figure 2 is an idealized drawing of a cracked area showing how the cracks tend to separate the soil mass into a maze of hexagonal cylinders.

In most soils the infiltration rate is measured with 8-inch-diameter ring infiltrometers. These infiltrometers are driven 6 inches into the soil and a constant head (usually 2 inches) of water is maintained over the soil. The infiltration rate is computed from the volume of water which enters the soil per unit of time. The ring is buffered by a larger concentric ring in which the same head of water is maintained. The purpose of this is to minimize lateral spread of water.

The impermeable nature of Sharkey clay makes it very difficult to predict the infiltration rate of the soil from standard ring infiltration tests. The ring infiltrometer, when used on Sharkey clay, gives a very low infiltration rate because it must be placed in an uncracked area. It would be meaningless to place it over a crack, as the water would immediately pass out through the crack. However, the low infiltration rates obtained with the ring infiltrometer are not representative of the initially high intake rates of Sharkey clay under actual field conditions.

Another method of measuring infiltration is the basin method, in which a constant head of water is maintained in a large basin. The

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FIGURE 1.—Cracks in Sharkey clay soil. Large cracks divide the soil mass into hexagonal cylinders. Small hairline cracks also develop in the upper layer. Flaking of soil surface is often observed.

amount of water absorbed per unit area per unit of time is the infiltration rate. The basin gives the true infiltration rate of the soil.

The basin infiltrometer has been used by many investigators, and in many respects it gives the most accurate results of all, especially if the basins are buffered. Although good accuracy results from the smaller effect of errors in measurement when a large volume of water is used, and from the greater soil surface area involved, the basin infiltration measurement requires a semi-permanent installation and is time-consuming and unwieldy to use.

Objectives

The objectives of this study were (1) to determine the effect of cracks and soil moisture content on the infiltration rate of Sharkey clay, and (2) to discover the relationship, if any, between basin infiltration rates and ring infiltration rates.

The method was to determine simultaneously basin infiltration rates and ring infiltration rates. The rates were measured over a wide range of moisture contents and crack widths on two plots at Baton Rouge, La.
FIGURE 2.—Configuration for major soil cracks. For this idealized configuration the volume of void space in the cracks can be computed from average crack width at the soil surface (CW), the average crack depth (D), and the diameter of the hexagonal blocks (Z).

Related Studies

The occurrence of soils which crack when dry is world wide. T. N. Jewett and K. R. Middleton (26),¹ in writing of the Sudan, said: “The irrigated clay soils of the central Sudan all crack deeply during the dry season and even between irrigations considerable cracks develop. Such cracks have been traced to three feet in Hezita soil and, with this rather impermeable soil, it seems likely that these cracks are the route by which immediate replenishment of the deeper soil takes place during irrigations. The function of cracks... is one of the vital problems of the irrigation of heavy clay soils such as those we deal with in the Sudan.”

Dr. Robert Smith and Vernon C. Robertson (47) in 1956 classified

¹Italic numbers in parentheses refer to Bibliography, Page 25.
some of the ancient irrigation lands of Mesopotamia and commented on the cracked clay soils there as follows: "When examined in pits, the dry soils usually show a dense blocky structure extending to a depth of about a meter. The soil mass is separated by extensive cracks which penetrate to about half a meter. When wetted, the soil mass tends to swell and the cracks close up. . . The hummocks form as the result of soil heaving when the soil is wetted following a dry season, when deep cracks develop and soil material from the surface falls down the cracks."

The phenomenon of soil falling down into cracks and thus slowly turning itself over for a period of years occurs in Sharkey clay, and such a soil is termed a "self-swallowing" soil (31).

W. O. Smith (48) in 1959 said that infiltration into clay soil with block structure takes place through the cracks, and then is absorbed into the individual soil peds (individual soil structural units). The absorption into the peds is strictly a capillary process. After the soil has swelled and closed the structural pore spaces of the soil, however, the flow of water within the soil is governed solely by Darcy's law.

In view of Smith's theory about water being absorbed by the individual soil structural units, it would be logical to assume that infiltration might be proportional to the total surface area of soil structural units exposed. This theory is supported by Horton (23), who in 1940 stated that, for clay soils which crack, "The principal factor involved in the variation of infiltration capacity is the area of exposed surface of sun-checks (cracks) and this unquestionably varies with the degree of swelling of the colloids within the soil adjacent to the walls of the sun-checks."

When a deeply cracked Sharkey clay is suddenly flooded with water, it would seem that the water would infiltrate into the soil in a horizontal direction from the cracks as well as in vertical direction from the surface. The principle of horizontal movement of water into soil has been examined by D. Swartzendruber (55) of Purdue University. His studies have been concerned with the effect of vertical channels made with a subsoiler and blown full of chopped foliage.

**Experimental Procedure**

**Plots Used in the Study**

Two plots, referred to as Plot 1 and Plot 2, were used in this study. Plot 1 was located in a small field adjacent to the Agricultural Engineering Shop on the Louisiana State University campus. The field had been under cultivation for an indefinite period of time. The plot was located near a dredged ditch in order to provide good surface drainage.

The soil at Plot 1 was a Sharkey clay with a blocky surface structure. A textural analysis of the soil was made by the hydrometer method and showed the soil to be 6.45 per cent sand, 38.53 per cent silt, and 55.02 per cent clay.
At the time of the study the field was covered with a sparse growth of grass and weeds. The plot was graded smooth with a blade about 2 months before the actual infiltration tests were made and, at the time of the tests, was practically barren of vegetation.

Plot 2 was located in a pasture about a mile from Plot 1. The plot had been in cultivation for an indefinite period of time. Located adjacent to a dredged ditch in order to provide good drainage, the plot was graded smooth about a month before the infiltration tests. At the time of the tests, the plot was practically barren of vegetation.

A plastic shed was erected over Plot 2 in order to help dry out the soil, since at the time of the test runs (December) it would have been difficult to dry the soil under natural conditions. Plot 2 dried out much slower than Plot 1 and, perhaps as a consequence of this, the cracks were farther apart and larger than on Plot 1.

Plot 2 differed from Plot 1 in having a higher percentage of clay. Its texture was 4.65 per cent sand, 31.70 per cent silt, and 63.65 per cent clay. It was noticeably "stickier" and harder to work than Plot 1. Judged entirely from appearance, the organic matter content of the two plots appeared to be the same.

The purpose of maintaining the surface in a bare, relatively smooth condition was to emphasize and isolate the effect of the cracks on infiltration. It was believed that the sparse vegetation on the plots would have little effect on the results.

**Basin and Ring Infiltration Measurements**

The infiltration rate of cracked soil was determined using 50.25-inch diameter rings for basin infiltrometers. The basin infiltrometers were made this size in order to enclose a large area of cracked soil. The rings were driven 8 inches into the ground at the test sites shortly before each run. Buffer rings 60 inches in diameter were then installed to prevent lateral losses of water. After installation of the rings, the soil surface was covered with a sheet of microfilm plastic and the ring filled with a 2-inch head of water (Figure 3). The infiltration rate of uncracked soil was determined simultaneously using 8-inch-diameter ring infiltrometers set on a homogeneous soil block (Figure 4). Each set of basin infiltrometer determinations was duplicated with a set of 8-inch single ring infiltrometer determinations in an adjacent uncracked area in order to provide comparison between the two methods. Each combination of the two determinations was termed a run. Twelve runs were made at one field plot and six were made at the other. Normal soil moisture depletion over a 3-month period at the test sites permitted infiltration runs to be made over a wide range of soil moisture conditions.

At the start of a run the plastic lining in the basin infiltrometer was removed and the infiltration test started. The head of water was maintained at 2-inch depth throughout the test by a solenoid valve actuated by a float switch which released water from a calibrated tank.
FIGURE 3.—Microfilm plastic in basin infiltrometer. The film was used to allow initial filling with 2 inches of water. When test run began, the plastic film was quickly removed. Hose supply from calibrated tank provided make-up water.

It was found that the water surface would become stabilized enough to permit accurate measurements within about 45 seconds after removal of the plastic. Frequent observations of the calibrated tank level and time gave the infiltration \((I_b)\) as a function of time \((T)\).

Water was supplied to the 8-inch ring infiltrometer in a manner different from that used for the basin infiltrometer. An airtight water container was placed on a Friez self-recording rain gauge weighing mechanism and a 1/4-inch rubber tube was attached to the bottom of the water container (Figure 4). The tubing led directly to the surface of the water in the ring. The bottom of the tube was 2 inches above the surface of the soil, and when the water subsided below this level, air was admitted to the tubing and enough water released to bring the level up to 2 inches. The rain gauge method of recording water infiltration was found to be very reliable, and long records of infiltration could be obtained with little effort. As a practical matter, the Sharkey clay was so impermeable that very little infiltration took place after the first 5 minutes, so the pen trace on the chart was usually almost a straight line after that time.

Before and after each run the moisture content (weight basis) of the 0- to 36-inch profile was determined by taking moisture samples at 6-inch intervals down to 36 inches. Also, the width and depth of cracks were measured before each run.
FIGURE 4.—Ring infiltrometer. A weighing type rain gauge mechanism (a) fitted with inverted water bottle provided continuous record of water infiltration in the 8-inch ring (b). Outer guard ring was replenished with water periodically.

A total of 18 runs were made, but because of mechanical difficulties it was not possible to record basin data from runs 1, 2, and 3. Also, it was considered that runs 5, 6, and 7 were too short to be used in an analysis of data. On the basis of observations during runs and examination of data from all infiltration tests, it was evident that runs 17 and 18 had leaked. Also, after run 15 was started it was observed that the
soil at that location contained a soil anomaly which made it unlike the other runs.

Accordingly, runs 4, 8, 9, 10, 11, 12, 13, 14, and 16 were finally left to be used for analysis.

**Results**

**Moisture Profiles**

In Figure 5 is plotted a graph of the initial and final moisture content of the soil for two typical runs. The curves show that most of the moisture change took place in the upper 8 inches of soil. The initial curves show that soil moisture content was high starting at a depth of about 12 inches below the soil surface. On the basis of field measurements and observations, it was found that cracks usually extended down to the upper side of this zone of high moisture content. The lower moisture content measured below 18 inches was probably due to higher soil density at deeper depths. The soil at this depth was more confined by the weight of the overlying soil and could not expand when it absorbed water. Therefore, it had a lower moisture content than the soil above it.

Comparison of the initial and final moisture content curves shows that part of the water applied never reached the bottom of the profile. In fact, the bottom of the soil profile often failed to receive moisture while the infiltration tests were in progress. The soil deeper than the deepest cracks was so impermeable that its moisture content was relatively independent of surface conditions.

**Basin Infiltration Rate**

Observations and measurements during basin studies indicated that cracks began to close soon after water was applied and within 65 minutes were apparently closed (Figure 6). By that time only a faint trace of the original crack outline could be seen. However, by testing with a sharp probe it was discovered that the cracks, although apparently closed, were in reality filled with soft mud. The soil between the cracks was much harder than the mud in the cracks.

A preliminary examination of the basin infiltration data indicated that a relationship of the form \( I_b = K T^n \) would adequately describe the basin infiltration for each level of soil moisture content.

The equations in Table 1 are plotted in Figures 7 and 8. The equation \( I_b = K T^n \) is a proper equation form to use in characterizing the basin infiltration at each level of moisture content, considering the high values of \( R^2 \) which were obtained.

The effect of the two parameters, soil moisture content and crack size, on the infiltration rate was evaluated with simple correlation and multiple regression analyses. For each individual basin infiltration run the multiple regression analyses provided the coefficient \( K \) in the relation \( I_b = K T^n \). Measurement of major crack width and depth for each run provided data for estimation of crack volume. Correlation of crack
FIGURE 5.—Moisture profile before and after infiltration for two runs. Note how average soil moisture content shows large change at soil surface but changed very little at depths below 18 inches. For run 13, soil continued to dry at 30-inch depth during infiltration test.
FIGURE 6.—Crack width change with time during surface flooding. Major cracks in Sharkey clay begin closing 10 minutes after wetting and appear to be fully closed after 1 hour. Actually, cracks when apparently closed are filled with soft mud.

Volume (surface inches of water per square foot) and infiltration coefficient $K$ indicated a very weak negative relation, $R^2 = 0.084$. 
TABLE 1.—Basin Infiltration Rates for the Two Test Plots

<table>
<thead>
<tr>
<th>Infiltration equation</th>
<th>Multiple correlation coefficient $R^2$</th>
<th>Average moisture content, 0- to 36-inch depth</th>
<th>Average crack width (inches)</th>
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</thead>
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<tr>
<td>$I_b = 0.6413 T^{1.92}$</td>
<td>.98</td>
<td>26.0%</td>
<td>.25</td>
</tr>
<tr>
<td>$I_b = 0.4980 T^{1.87}$</td>
<td>.93</td>
<td>26.8%</td>
<td>.07</td>
</tr>
<tr>
<td>$I_b = 0.6635 T^{0.92}$</td>
<td>.86</td>
<td>33.2%</td>
<td>.07</td>
</tr>
<tr>
<td>$I_b = 0.6116 T^{0.793}$</td>
<td>.94</td>
<td>30.2%</td>
<td>.07</td>
</tr>
<tr>
<td>$I_b = 0.6387 T^{0.679}$</td>
<td>.90</td>
<td>30.2%</td>
<td>.07</td>
</tr>
<tr>
<td>$I_b = 0.4686 T^{0.727}$</td>
<td>.77</td>
<td>31.3%</td>
<td>.07</td>
</tr>
<tr>
<td>$I_b = 1.125 T^{1.287}$</td>
<td>.97</td>
<td>34.8%</td>
<td>.62</td>
</tr>
<tr>
<td>$I_b = 0.6008 T^{1.608}$</td>
<td>.95</td>
<td>40.0%</td>
<td>.25</td>
</tr>
<tr>
<td>$I_b = 0.6790 T^{1.848}$</td>
<td>.99</td>
<td>38.3%</td>
<td>.50</td>
</tr>
</tbody>
</table>

Although the presence of cracks is highly important in determining infiltration rates, the actual contribution of the crack volume to the initial infiltration is relatively small. It appears that the initial large amount of water which infiltrates the soil is partially absorbed by the extremely dry surface crust and the cracks. The slow infiltration which then follows takes place downward from the surface and laterally from the cracks.

The effect of average soil moisture content and crack size was also evaluated with multiple regression analyses using an equation form:

![Figure 7](image-url)

**FIGURE 7.**—Basin infiltration for six runs on Plot 1 (55 per cent clay). Basin infiltration rate increased with decrease in soil moisture content. Even for driest soil condition hardly more than 2 inches of water infiltrated into the cracked clay soil.
FIGURE 8.—Basin infiltration for three runs on Plot 2 (64 per cent clay). Total infiltration was 5 inches for dry soil condition.

\[ I_b = K (MC)^m (CW)^p T^n \]  

where

- \( I_b \) = infiltration, inches
- \( K \) = a coefficient
- \( MC \) = average soil moisture content, 0.36 inches, per cent
- \( CW \) = crack width, inches
- \( m, n, p \) = exponents
- \( T \) = time, minutes.

The regression analyses were run with pooled data from each test plot with automatic deletion of the least important variable, and then repeated. In this manner it was a simple matter to determine the relative importance of the variables and the confidence limits that could be placed on the equation.

The data from Plot 1 (55 per cent clay) gave the following results:

- Deleting CW, the equation is
  \[ I_b = 6320 \ MC^{-2.7701} \ T^{1.269} \]  
  \( ; \ R^2 = .809 \)  

- Deleting MC, the equation is
  \[ I_b = .5392 \ T^{1.1458} \]  
  \( ; \ R^2 = .374 \)

The above analysis indicates that the CW factor is of little importance since deleting it from the equation changes the \( R^2 \) value very little. Only 5.2 per cent of the variation in \( I_b \) is accounted for by crack width.
The data from Plot 2 (64 per cent clay) gave the following results:

\[ I_b = 5.8915 \times 10^{10} MC^{-6.9435} CW^{-1.1225} T^{1.1969} \quad ; \quad R^2 = .980 \quad (H) \]

Deleting CW, the equation is

\[ I_b = 7.2075 \times 10^9 MC^{-6.3388} T^{1.1970} \quad ; \quad R^2 = .979 \quad (I) \]

Deleting MC, the equation is

\[ I_b = .7792 T^{2.059} \quad ; \quad R^2 = .527 \quad (J) \]

As was the case with Plot 1, the CW factor was of slight importance, accounting for 0.1 per cent variation in \( I_b \), but the MC factor was significant in influencing the infiltration rate. The validity of equations (F) and (I) was demonstrated by plotting \( I_b \) (predicted) versus \( I_b \) (observed) in Figure 9. It can be seen by an examination of Figure 9 that the predictions are reliable.

It was hypothesized that the value \( K \) in the equation \( I_b = KT^n \) would be proportional to the size of the cracks present at the beginning of a run. However, results of this study failed to bear this out.

**FIGURE 9.**—Scatter diagram of predicted infiltration and observed infiltration. The 45-degree line is line of perfect agreement. Predicted values are solutions to equations (F) and (I).
Ring Infiltration Rate

Ring infiltration data for each test site were analyzed with multiple regression using the equation form

\[ I_r = K \ (MC)^m T^n. \]

No clear relationship was found for the effect of moisture content (MC) on infiltration rate. For Plot 1 the exponent of MC was positive but for Plot 2 it was negative. Very poor correlation with the above equation form was found. Pooled data equations for ring infiltration for each plot were computed:

(Plot 1) \[ I_r = 0.965 T^{0.0352} \]  
(Plot 2) \[ I_r = 0.734 T^{0.0320} \]

There were significant correlations between \( I_r \) and \( T \) at the 0.001 and 0.1 levels, respectively. Curves (K) and (L) are plotted in Figure 10.

Ring infiltration equations \( I = KT^n \) for the individual runs were also derived from regression analyses. Simple correlation of coefficient \( K \) and moisture content for all runs yielded a very weak relation. It was concluded that soil moisture content based on average value for depth 0 to 36 inches is not an adequate parameter for ring infiltration behavior for Sharkey clay. Swelling of the wet surface soil controls the infiltration rate shortly after the initial water application, making the infiltration rate independent of average soil moisture content in the 0- to 36-inch profile.

The most important feature of ring infiltration in Sharkey clay is that virtually all the infiltration takes place in the first few minutes, and the initial infiltration is a fairly fixed amount, which ranges from 0.48 to 1.0 inch.

FIGURE 10.—Ring infiltration rate. The effect of soil moisture content on 8-inch ring infiltration was erratic. The pooled data for all runs were used for computing the infiltration equations (K) and (L).
Comparison of Basin and Ring Infiltration Rates

Differentiation of basin and ring infiltration equations (F) and (K) for Plot 1 yields:

\[
\frac{DI_b}{DT} = 802 \text{ MC}^{-2.77} \text{ T}^{-0.873} \quad \text{(M)}
\]

\[
\frac{DI_r}{DT} = 0.0340 \text{ T}^{-0.965} \quad \text{(N)}
\]

and for Plot 2 differentiation of (I) and (L) yields:

\[
\frac{DI_b}{DT} = 1.421 \times 10^9 \text{ MC}^{-6.34} \text{ T}^{-0.803} \quad \text{(O)}
\]

\[
\frac{DI_r}{DT} = 0.0234 \text{ T}^{-0.968} \quad \text{(P)}
\]

where \( DI/DT \) = infiltration rate, inches per hour.

Equations (O) and (P) are plotted in Figure 11 for visual comparison of basin and ring rates. Note that \( DI/DT \) more rapidly approaches zero for ring infiltration than for basin infiltration. Basin infiltration rates were influenced by the presence of cracks, while the ring infiltration was uninfluenced by cracks. Furthermore, the difference in infiltration rates persisted throughout the duration of each run, indicating that the cracks had an effect not only on the initial infiltration rate, but also on the infiltration rate for the entire run.

The most striking characteristic of infiltration rates of Sharkey clay is the rapidity with which they decrease. For example, an examination of Figure 11 will show that for Plot 2, \( DI_b/DT \) after 100 minutes was

![Figure 11](image-url)
only 0.34 inch per hour. It is apparent that the DI₀/DT for Sharkey clay approaches a very low value, regardless of the initial soil moisture content.

The question of whether DI₀/DT actually becomes zero after long periods of infiltration was not answered by the data of this experiment, as all individual runs were terminated in less than 48 hours. After about 24 hours had passed, it was considered that the evaporation rate of approximately 0.2 inch per day was greater than the infiltration rate.

Other workers in the field of infiltration, notably Horton (23), have frequently mentioned a "final steady rate" of infiltration for various soils. Ordinary soils often have a final steady rate of infiltration which is the same order of magnitude as their saturated permeability. It is possible that the final steady rate of infiltration for Sharkey clay is the same as the permeability, which has been listed as low as zero inch per hour. On the other hand, it is possible that the presence of crack channels causes Sharkey clay to have a final steady rate of infiltration slightly above zero.

**Effect of Soil Moisture Content on Crack Size**

A rough general relationship exists between soil moisture content and crack width for any given soil. Field measurements were too few to establish a reliable relationship because of the limited number of samples. In an attempt to obtain more precise data, a laboratory experiment to determine the exact width of the surface cracks as a function of moisture content was initiated. Soil from the plots was placed in a shallow pan and well puddled, and then allowed to dry. The point at which the soil first gave visible sign of shrinkage was arbitrarily defined as the cracking point. At this point the soil began to show evidence of hairline cracks. As the soil dried out more, the cracks became wider as shown in Figure 12. The cracking point for Plot I was found to be 39.34 per cent. It was noted that the shrinkage rate changes at the shrinkage limit, or that moisture content below which the soil does not shrink with further reductions in moisture content.

It was possible to estimate the depth of cracks in the field plots by referring to soil moisture profiles (Figure 5), which show soil moisture content versus depth. The surface layer of soil, which was at a moisture content below the shrinkage limit, had wide, fully-developed cracks.

The crack width cannot be correlated with the moisture content of the top of the surface layer because this is always well below the shrinkage limit and the edges have sloughed off. It is difficult to correlate it with layers below the surface, because here the moisture gradient is so great, going from, say, 6 per cent to 35 per cent in 4 or 5 inches. However, cracks begin developing at about 39 per cent moisture and continue to develop until all of the surface soil reaches the shrinkage limit. As the top layer dries down past the shrinkage limit, it ceases to shrink further, but layers immediately below the surface which are
FIGURE 12.—The effect of soil moisture content on major crack width. Drying the soil causes increase in crack width until a constant value is reached. The moisture content at this point is close to shrinkage limit value for the soil.
still above the shrinkage limit continue to shrink, and the edges of the top layer crumble down into the cracks.

It would seem that plants growing on Sharkey clay are subjected to some unusual stresses. The non-capillary porosity is so low that the poor aeration of the soil must be a severe limitation to plant growth, except when the soil is deeply cracked. After irrigation, the surface soil becomes 100 per cent saturated and this prevents proper aeration of the plant roots. The cracking of the soil as it dries out perhaps does harm to the young plant roots. Judging from the before-and-after curves of moisture content versus depth, it can be seen that practically all movement of water into the soil is confined to the upper 12 to 18 inches, or the depth to which cracks most commonly occur. Virtually all plant rooting probably takes place in this upper 12 to 18 inches. Thus, in Sharkey clay we have the paradox of a deep, fertile, alluvial soil which is yet somewhat droughty.

**Irrigation Rates for Sharkey Clay**

Equations (G) and (J) can be used for calculating time required to accomplish irrigation. In Figures 13 and 14 the total time required to apply 1, 1½, and 2 inches of water to Sharkey clay is plotted as a function of moisture content for the plots. The striking effect of soil moisture content upon the time required

![Figure 13](image-url)

**FIGURE 13.**—Time required to complete 1-inch, 1½- and 2-inch irrigation for Sharkey clay on Plot 1. Irrigation time requirement depends on initial soil moisture content. For example, if irrigation is begun at wilting point (27.06 per cent moisture content), 35 minutes are required for a 1-inch flood irrigation.
for an irrigation is shown by the following: When the moisture content was 34.8 per cent, the time required to apply 1 inch of water was less than 1 minute and to apply 2 inches was 18 minutes, whereas when the soil moisture content was 40.0 per cent, it required 18 minutes to apply 1 inch of water and 1,480 minutes to apply 2 inches.

Ideally, to accomplish an irrigation in the least amount of time, the total amount of water required for the irrigation should be applied to the field as fast as possible. If it is not practical to flood the field with the entire amount of water, it is suggested that the initial amount of water applied to the soil be equal to or greater than the amount which will be absorbed by the soil in 1 hour. The remaining water may be applied at rates equal to the infiltration rate, $\frac{DI}{DT}$ given by equations (F) or (G).

As the term is commonly used, average design rates for a Sharkey clay have little meaning. Reference to Figure 11 will show that the $\frac{DI}{DT}$ changes so rapidly that an average value would be of little practical use. Applying water at an average rate would mean that during the early part of the irrigation the soil would soak up the water faster than applied, and at later stages of the irrigation the water would be applied faster than it could soak into the soil.

**Summary and Conclusions**

The purposes of this study were (1) to determine the effect of cracks and soil moisture content on the infiltration rate of Sharkey clay, and (2) to discover the relationship, if any, between basin infiltration rates and ring infiltration rates.
From the results of the study the following conclusions are drawn:

1. Basin infiltration rates are not directly related to ring infiltration rates. Ring infiltration rates in Sharkey clay are very low after the first few minutes. In general, the total amount of water which will penetrate Sharkey clay by ring infiltrometer is in order of magnitude about 1 inch. Basin infiltration in Sharkey clay has a considerably higher rate at all times than ring infiltration. Under basin infiltration about one-half of the total volume of irrigation water enters the soil in about 90 seconds.

2. Infiltration into Sharkey clay can be expressed by the following equations:

For soil containing 55 per cent clay:

\[ I_b = 6320 \, MC^{-2.77} \, T^{1.27} \]  
\[ \frac{DI_b}{DT} = 802 \, MC^{-2.77} \, T^{-0.875} \]  

For soil containing 64 per cent clay:

\[ I_b = 7.21 \times 10^9 \, MC^{-6.34} \, T^{1.1970} \]  
\[ \frac{DI_b}{DT} = 1.421 \times 10^9 \, MC^{-6.34} \, T^{-0.892} \]

3. By comparing infiltration rates of cracked and uncracked areas at the same moisture content, it has been shown that cracks cause a significant increase in infiltration rates. The contribution of the cracks to increased infiltration rates was due to their acting as downward passageways for water to travel through, and not because of their volume alone. The effect of the cracks continued even after they had appeared to swell shut.

4. During irrigation of Sharkey clay most moisture changes occurred in the upper 8 inches of the soil profile. The upper portion of the soil profile was usually 100 per cent saturated after each infiltration run. This, combined with the low non-capillary porosity (6.6 per cent for this soil), results in poor aeration of plant roots for a period after each irrigation, and probably is the reason why crops on Sharkey clay tend to be shallow rooted and susceptible to drought.

5. Design rates for irrigating Sharkey clays have been indicated. The concept of an average design rate is not well suited to this soil. Instead, a rapid flooding of the soil with the entire amount of irrigation water desired appears to be more practical.
Bibliography


